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HOW TO BUILD A STAVE SILO.[a]

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SIZE AND LOCATION.

Diameter.—In determining the size of a silo the first thing to be considered is the diameter, and this depends on the number of cattle to be fed. When the diameter of a silo is too great the silage is not fed off rapidly enough to prevent some of it from spoiling. This is particularly true when silage is fed in summer. Care should therefore be taken that the diameter of the silo be not too great for the number of cows to be fed from it. Table 1 shows the least number of dairy cows that should be fed from silos of diameters given:

TABLE 1.—*Showing ratio between diameter of silo and number of cows to be fed.*

Diameter of silo (in feet).	Number of cows to be fed.
10.....	12
12.....	17
14.....	23
16.....	30
18.....	38

From 30 to 40 pounds of silage per cow per day should be provided for average dairy cows during the time when no other green feed is available, and the foregoing table is based on this rate of feeding. The amount varies according to the quantity and quality of dry forage used.

Height.—After the diameter of the silo has been decided upon the next consideration is the number of tons of silage that will be needed, and this depends on the length of the silage-feeding season. When the number of tons and the diameter have been fixed upon, a refer-

[a] Circulars giving directions for building other types of silos are in preparation, and when issued may be obtained on application to the United States Department of Agriculture, Washington, D. C.

ence to Table 2 will indicate what the height of the silo should be. For example, if the diameter is to be 14 feet and the capacity 100 tons, the height should be 32 feet.

TABLE 2.—*Height of silo needed for a given capacity with a given diameter.*

Height of silo.	Capacity of silo having an inside diameter of—						
	10 feet.	12 feet.	14 feet.	15 feet.	16 feet.	17 feet.	18 feet.
Feet.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
20	26	.....	.....	.....	.....	.....	.....
22	30	43	.....	.....	.....	.....	.....
24	34	49	.....	.....	.....	.....	.....
26	38	55	74	.....	.....	.....	.....
28	.....	61	83	95	.....	.....	.....
30	.....	.....	93	105	119	.....	.....
32	.....	.....	101	115	130	148	.....
34	.....	.....	.....	125	143	161	181
36	.....	.....	.....	.....	151	174	196

A convenient height for a silo above the foundation is twice its diameter; but sometimes it is necessary for a silo of small diameter to be higher than this. In such a case it should be well braced.

Location.—The silo should, if possible, be located so as to open into the feed room. If such arrangement is impracticable, it should be located near the barn at some other point and connected with the barn or with the feed room by a covered passageway.

THE FOUNDATION.

To lay out the foundation, drive a stake in the ground at the center of the proposed silo. Saw off this stake at the height desired for the foundation wall, which should be at least 1 foot above the ground on

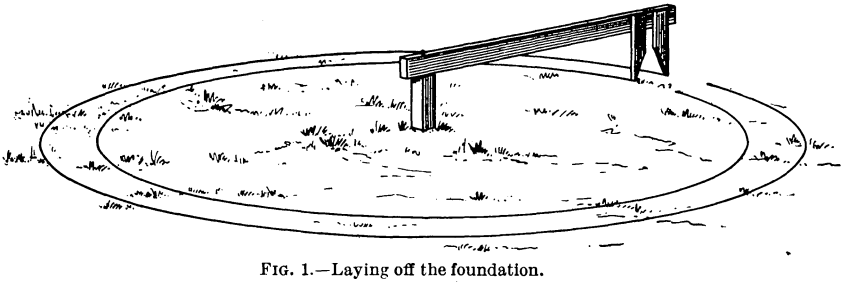

FIG. 1.—Laying off the foundation.

the high side if the ground is sloping. One end of a straight 2 by 4 inch scantling, a little longer than is necessary to reach from the center of the silo to the outside of the foundation wall, should be nailed on top of the stake with a 40-penny spike. This spike then marks the exact center of the silo. From it measure off on the scantling the distance to the inside and outside of the foundation wall, and, having nailed on markers, as shown in figure 1, lay off the foundation.

The thickness of the wall should vary from 10 to 18 inches, depending upon the size of the silo, the material of the foundation, and the ground on which it is located. The inside of the foundation wall should be at least 2 inches nearer to the center of the silo than the inside of the staves. Where the ground on which the silo is to be located is not level, the markers can be lengthened by holding a longer board against either marker (see fig. 2), moving it up or down to keep it touching the ground while the scantling is *held level.* If the ground is very uneven it may be difficult to make the line continuous, in which case points can be marked every few inches and these joined afterwards.

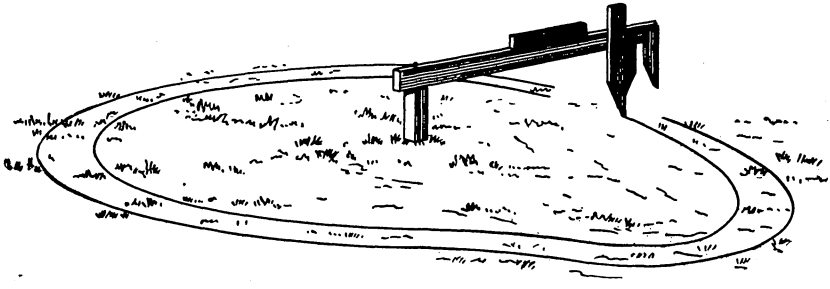

FIG. 2.—Laying off the foundation on sloping ground.

MATERIALS AND CONSTRUCTION.

The material of the foundation may be stone, brick, or concrete. Concrete is preferable under most conditions. Where stone or brick is to be used the earth in the bottom of the silo, except where the center stake stands, may be dug out before the wall is built, thus giving additional silage space and allowing greater convenience in building the wall. The earth should not be dug out deeper than 4 inches above the bottom of the wall. With a concrete foundation this excavation must not be made until the wall has been finished and the position of the staves marked on the top of the wall.

Stone.—Stone may be conveniently used when the foundation will not extend more than 1 or 2 feet above the surface of the ground. It should be laid in cement mortar in such a manner that the inner surface will be smooth and the top level.

Brick.—Where hard-burned brick can be secured cheaply, as is often the case near brickyards, they can frequently be used to advantage for a foundation. They should be laid in cement mortar, with the inner surface of the wall smooth and the top level. If the wall extends more than 1 foot above the surface it should be reinforced by laying a No. 9 wire, or its equivalent, on every second course of brick above the surface of the ground.

Concrete.—For a concrete foundation, a ditch must be dug before any of the earth in the center is removed (see fig. 3). The earth

between the two lines that mark the inside and outside of the foundation should be taken out until firm ground below frost line is reached, care being taken to cut the sides of the ditch down straight and to leave the bottom level.

The concrete should be made of one part cement, three parts sand, and five parts broken stone. The broken stone may be of all sizes up to pieces that will pass through a 2-inch ring. Washed gravel, broken brick or screened cinders may be used in place of broken stone. If the gravel contains sand the amount contained should be estimated

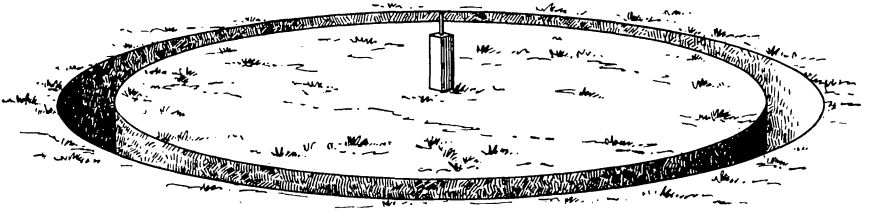

FIG. 3.—Ditch for concrete foundation.

by screening some of it, and the proportions of gravel and sand should be so adjusted as to conform approximately to the above formula.

Preparing the concrete.[a]—For mixing the concrete, a box about 4 feet wide, 8 feet long, and 1 foot deep may be used, or a simple floor or platform 6 by 10 feet will suffice. To measure the materials, an empty barrel (preferably a cement barrel) with both ends knocked out will be most convenient. First measure up sand enough for a batch of convenient size and spread it on the floor or platform. Measure up the cement, spread it over the sand, and, with a hoe or shovel, mix them until no streaks appear. This mixture is then built up into a low circular pile with a crater-like basin in the center. Into this "crater" pour water and, by drawing in the dry mixture from all sides with a hoe, mix thoroughly, adding more water if necessary until the hoe will leave the mortar without the mortar clinging to it, after which the mortar is spread out on one end of the platform. Now measure up the broken stone or coarse gravel, drench it with water to wash off all particles of dust, and dump it on the wet mixture of sand and cement. The final mixing is usually done by shoveling the material back and forth until it is thoroughly mixed. It should be shoveled at least three times. The concrete is now ready for use and should be put in place with as little delay as possible.

Filling the ditch with concrete.—Put in the first layer about 6 inches deep and thoroughly ram the concrete until water appears on the surface. A good rammer may be made of a piece of 4 by 6 inch

[a] Farmers' Bulletin 235 (Cement Mortar and Concrete, Its Preparation and Use) can be secured free of cost by addressing a request to the Secretary of Agriculture, Washington, D. C.

lumber, 2 feet long, with a hole bored in the center of one end to receive a 4-foot round handle. When the second layer is put on, the surface of the first layer should be perfectly clean and rough, and if dry it should be sprinkled with water. Particular care should be taken to keep all dust and loose soil from the surface of each layer, as these prevent perfect adhesion.

Building forms.—After the ditch is filled to the surface of the ground, drive 2 by 4 stakes half an inch from the foundation on the inside and 2 feet apart all the way round. (See fig. 4.) With a straight-edge placed level—one end on top of the center stake and the other against the side of the form stake—mark on the form stake the height that the wall should be, as previously determined. Mark thus on every second stake. Take pieces of lumber one-half inch thick by 6 inches wide, preferably green, with straight edges, and bend around outside of these stakes, nailing the boards to the stakes, with the top edge at the marks. Then saw off the tops of the stakes above the boards. (The necessity for this sawing may be avoided by driving down the stakes beforehand to the exact height.)

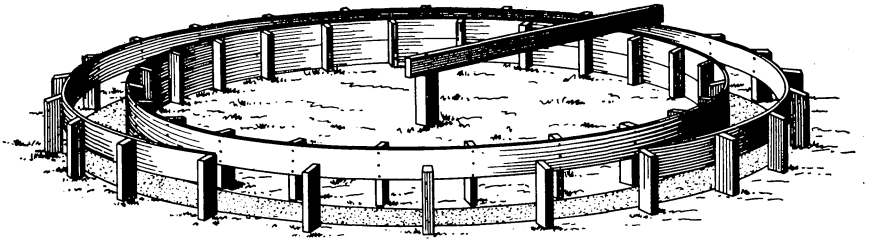

FIG. 4.—Form for foundation above ground partially boarded up.

After the space from the top board to the ground has been boarded in, drive stakes in a similar manner for the outside form half an inch from the concrete. Drive these stakes so that the scantling, resting on the center stake and the inside form, as shown in figure 4, will just clear the tops. Board up these stakes on the inside, making the top of the outer form level with that of the inner.

At several places nail slats across the top of the form to keep the inner and outer circles the proper distance apart. After all the boards are on, the form is ready to be filled with concrete. (See fig. 5.)

Filling the form.—Four or five eyebolts half an inch in diameter and from 20 to 24 inches long, with a hook or elbow on the lower end, should be placed 6 inches from the inside of the foundation and held in a vertical position by boards fastened across the top of the form. These bolts should extend 8 or 10 inches above the top of the wall. The concrete will be filled in around them. After the silo is com-

pleted the staves adjoining the eyebolts will be securely fastened to them.

If the wall extends more than 1 foot above the surface of the ground, it should be reinforced by embedding in the concrete, every 8 inches above the surface and near the outer edge, two or three strands of wire with ends tied together. After ramming each 6-inch layer of concrete, work a spade between the concrete and the form to force the coarser materials away from the boards, thus leaving smooth-surfaced walls.

When the concrete is within 1 inch of the top, finish with mortar made by mixing 1 part of cement to 3 parts of sand and strike off level with the top edges of the form.

After the concrete has set and before removing the center stake, mark a line with a nail, pencil, or crayon entirely around on top of the foundation wall 3 inches from the inner edge to show where the inside edge of the staves will come. (See fig. 5.)

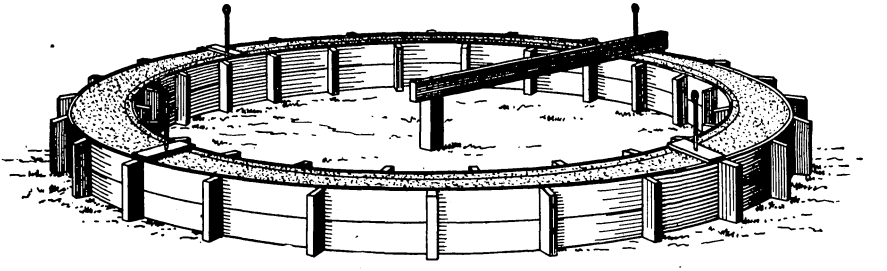

FIG. 5.—Form filled with concrete showing eyebolts and slats in place and circle to mark position of staves.

Next dig out the dirt inside the foundation to 4 inches above the bottom of the wall.

CONCRETE FLOOR.

If the earth in the bottom of the silo is firm and comparatively dry, no provision need be made for drainage, and a concrete floor is unnecessary. Still such a floor makes the silo easier to clean and makes it impossible for rats to burrow underneath the foundation wall and gain access to the silage. If, however, the earth in the bottom of the silo is inclined to be seepy, a tile drain should be laid in it and a concrete floor should be laid above the tile. The tiling should open into the floor at the center, and the floor should be made to drain to it. The tiling should extend beyond the silo wall and have its outlet lower than the floor. The entrance of the tile drain should be stopped with a wooden plug before the silo is filled and should be opened after the silo is empty.

The drain will not only carry off the water which tends to seep in but any rain water that may collect on the floor in case the silo has

no roof. The concrete floor should be made 4 inches thick, of concrete similar to that used in the foundation wall, and surfaced with mortar made of 3 parts sand to 1 part cement.

THE STAVES.

Lumber.—Cypress, long-leaf pine, white pine, cedar, and California redwood are good materials for silos. It is important that the staves be straight, and free from sapwood, loose knots, and waney edges.

Preparing the staves.—Staves should be made of 2 by 4 or 2 by 6 inch scantling, the latter being preferable, particularly for the larger silos. They should be of the same width and thickness and should be surfaced on one side and on both edges, the edges being left square.[a]

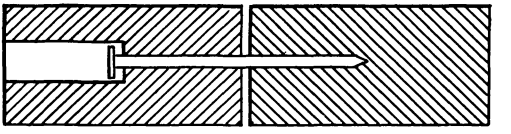

FIG. 6.—Cross section showing how two adjoining staves are spiked together.

After the staves are squared at the ends, holes should be bored in the edges from 4 to 6 feet apart with a half-inch bit. These holes are made on one side only of each stave, and must not be in line in adjoining staves. They should be about 1 inch deep in staves 4 inches wide, and about 3 inches deep in staves 6 inches wide. One of these holes should come within a foot or less of each end of the stave. Care should be taken to bore the holes perpendicular to the edge of the stave, to avoid having the silo thrown out of plumb. The purpose of these holes is to allow spiking the staves together when set up. The spike is driven into the bottom of the hole, and passes through the rest of that stave and into the adjoining stave, as shown in figure 6.

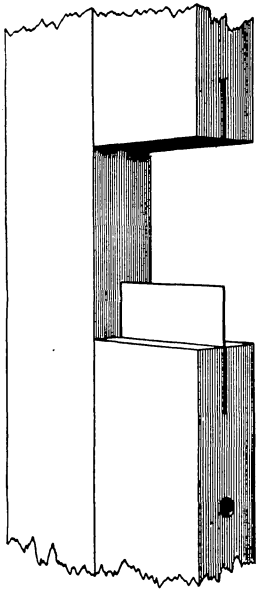

FIG. 7.—Showing how sections of stave are spliced together endwise.

Care should be taken not to put any spikes in those portions of the staves which are to be cut out for doors.

It is preferable that each stave be in one piece, but where this is impossible the staves should be of two pieces of different lengths, splined together by making in the ends to be joined a saw cut 1 inch deep and parallel to the sides of the stave, and inserting a sheet-iron spline (preferably galvanized), as shown in figure 7.

[a] It is considered necessary by some that the edges of the staves be beveled and tongued and grooved, but satisfactory results can be obtained by using square-edged staves, and at less expense.

Cutting the door stave.—Before the staves are put up it is necessary to decide how many doors the silo should have, that a door stave may be prepared.

TABLE 3.—*Number and spacing of doors in silos of different heights.*

Height of silo.	Number of doors.	Height of doors.	Space between doors.	Space below first door.	Space above last door.
		Feet.	*Feet.*	*Feet.*	*Feet.*
20 feet	4	2½	2½	1	1½
24 feet	4	2½	3	1	3¾
28 feet	5	2½	3	1	2½
30 feet	5	2½	2½	1	1½
32 feet	6	2½	2⅝	1	2¼
34 feet	6	2½	3	1	3
36 feet	7	2½	2½	1	2½

Table 3 will assist the builder in determining the number of doors and the distance between them. When this has been done the location of the doors is laid off on a stave and saw cuts are made half way through it. These are for the entrance of the saw in cutting out the doors after the staves are set up. The cuts should be made at a slant of 45 degrees on the edge of the stave but horizontal on the front, as shown in figure 8. (See also fig. 14.) The object of the slanting cut is to make the doors removable only toward the inside of the silo, and so that when it is full the pressure of the silage will hold the doors in place. The cut for the bottom of each door should slant downward from the outside to the inside of the stave; and the cut for the top of the door should slant upward.

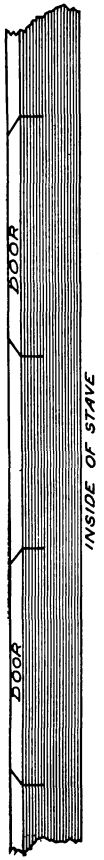

FIG. 8.—Stave partly cut through for doors

To prevent this stave from breaking while it is being handled, a slat should be nailed on one side of it. This slat should be removed after the stave has been put in position.

When the staves are being put up the door stave should be located at one side of the place where the doors are to be cut. After the hoops are put on the silo, a handsaw can be inserted in the saw cuts of the door stave for the purpose of sawing out the doors.

Setting up staves.—In order to nail the staves together at the top when they are being put up, it will be necessary to provide a scaffold. Where the silo is not to be over 25 feet high, a stepladder, as shown in figures 9 and 10, may be used. As the staves are put up the ladder can be moved along and kept in the right place from which to work.

The first stave (fig. 9, *a*) should be placed with its inner face on the line (fig. 5), 3 inches from the inner edge

of the foundation. It should be plumbed in both directions and securely fastened at top and bottom. For this purpose use braces nailed to stakes driven firmly in the ground, or to some adjacent building, as shown in figure 9. If this is not done the silo will be out of plumb.

The next stave is then set up and nailed to the first with 30- or 40-penny spikes. These spikes are started in the holes previously bored (fig. 6) and driven home with a driftpin. The spikes must not be driven at an angle up or down, for either of these will throw the silo out of plumb.

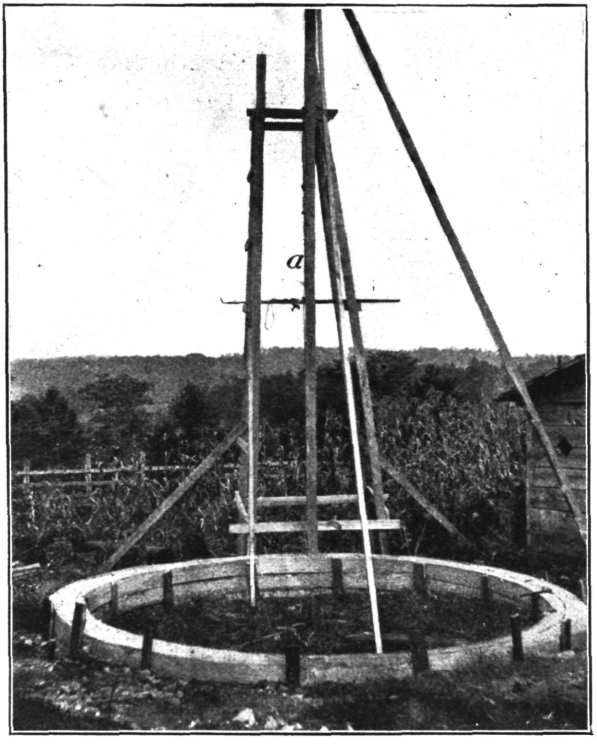

FIG. 9.—The first stave (*a*) in position.

Other staves should be put up as above described and as shown in figures 9 and 10, until the place is reached where the doors should be. The door stave, cut as previously described, should then be nailed in position and the remaining staves set up. In setting up spliced staves, the longer and the shorter staves should alternate. (See fig. 11.) Ordinarily it will only be necessary to have staves of two lengths, as, for instance, 16 feet and 12 feet for a 28-foot silo.

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Figure 11 shows all the staves in position ready for the hoops. The junction points of top and bottom pieces are shown; also the door stave with saw cuts part way through it.

THE HOOPS.

The hoops should be made of $\frac{3}{4}$, $\frac{5}{8}$, and $\frac{1}{2}$-inch rods, in sections from 10 to 14 feet in length. The ends of these rods should be threaded for 6 inches so that they may be joined together by means

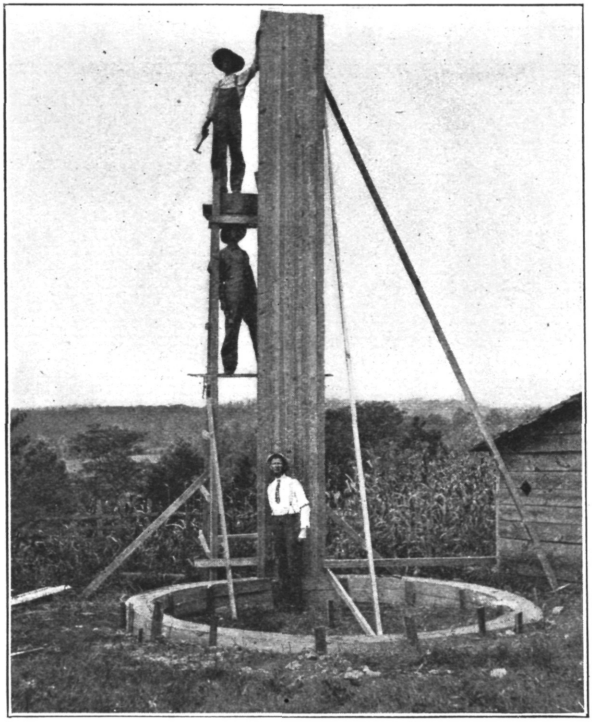

FIG. 10.—Several staves in position.

of lugs. For silos 14 by 30 feet the lower two-thirds of the hoops should be of $\frac{5}{8}$-inch rods, and the upper third of $\frac{1}{2}$-inch. For silos larger than 14 by 30 feet the lower third of the hoops should be of $\frac{3}{4}$-inch, the middle third of $\frac{5}{8}$-inch, and the upper third of $\frac{1}{2}$-inch rods.

Putting on the hoops.—Two hoops should be placed below the first door, two between doors all the way up, and two above the top door if this space is more than 2 feet; if less than 2 feet, one will be sufficient. Three or four hoops should at first be put on at the bottom and tightened up. Planks can then be thrown across the top of the silo to serve as a scaffold, so that the top hoop may be put on and tightened. The other hoops should then be put around the silo loosely, within reach of the ground, after which they are pushed

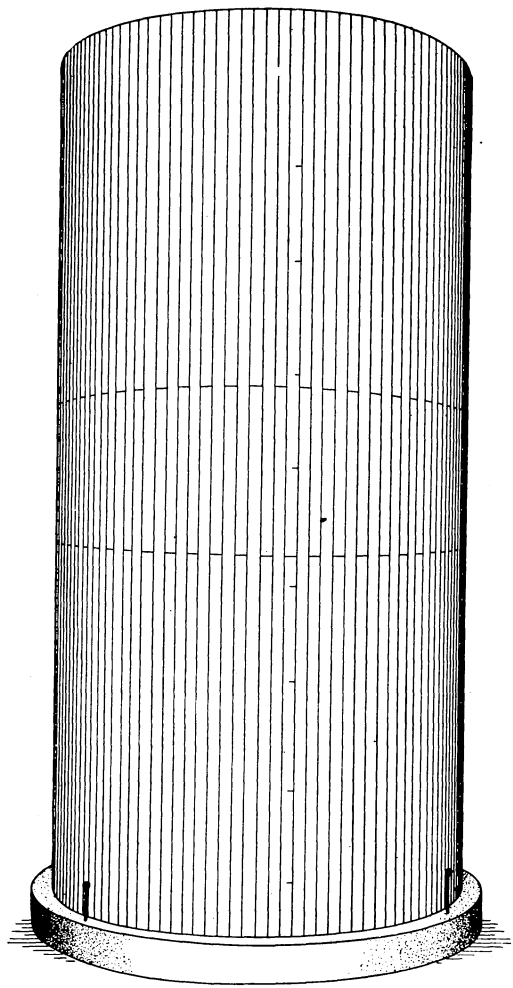

FIG. 11.—All the staves in position ready for the hoops.

up to the proper position with slats, and made fast by stapling them to the silo from a ladder. When all the hoops are in position they should be tightened until the staves are pressed close together. Staples should then be driven over each hoop 2 or 3 feet apart so as to hold the hoops in the proper position in case they get loose.

Joining hoops without lugs.—It is sometimes very difficult to get lugs for the hoops. In such cases 4 by 6 inch timbers may be put in instead of ordinary staves at the three or four points where the hoops will join. These timbers should be placed with the 4-inch face flush with the staves on the inside and they will extend 4 inches beyond the wall on the outside. Through these outside projections holes should be bored to receive the hoops and the ends may be fastened with nuts. Large iron washers should be used under the nuts. Such a method of connecting the hoops is shown in figure 12, but its use is advised only when the lugs can not be obtained.

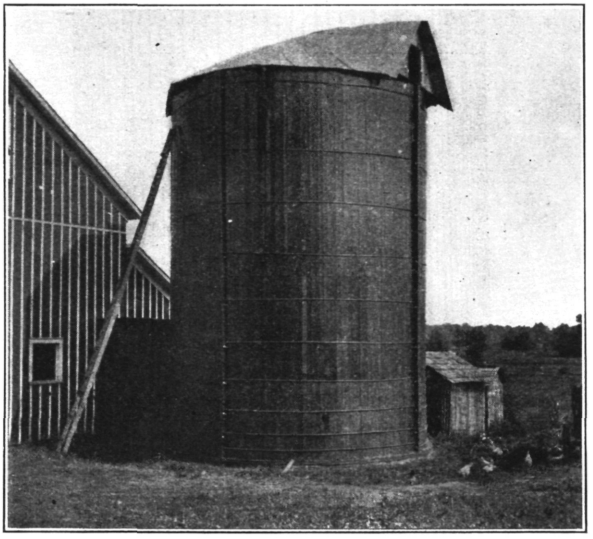

FIG. 12—Method of connecting hoops without lugs.

THE DOORS.

Sawing out and making.—After all the hoops are tightened, saw out the doors, beginning with the stave previously cut. The illustration (fig. 13) shows the lower door completely cut and the second one partly cut.

The doors should be about 20 inches wide and 30 inches high. The exact width will of course be determined by the width of the staves.

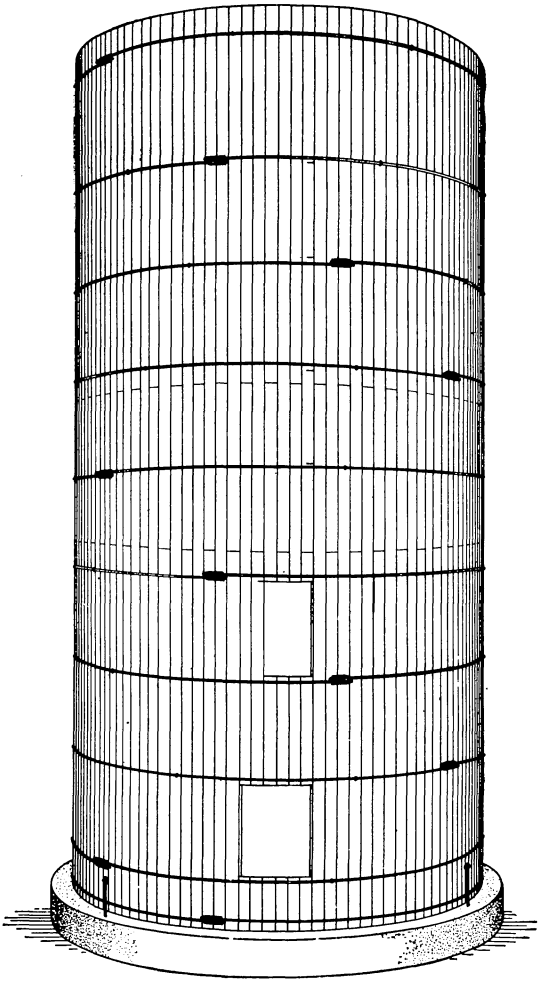

FIG. 13—Sawing out the doors.

Two cleats, 2 by 3 inches, with one edge cut to the circle of the silo, should be nailed and bolted on the outside of each door (fig. 14), with the nuts on the outside and the boltheads sunk flush with the inner surface. The bolts should be ⅜ inch by 5 inches. Four bolts in each cleat (2 at each end) will be sufficient; the cleat may be

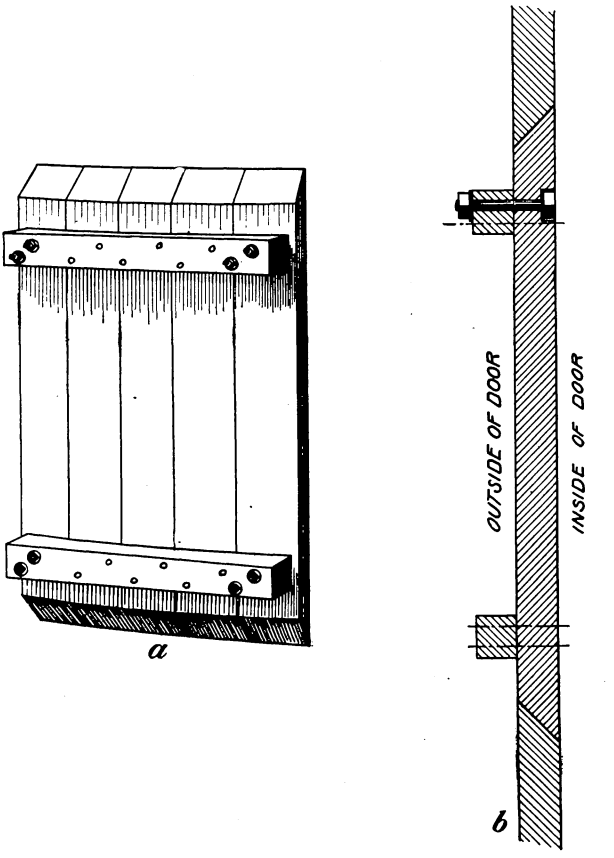

FIG. 14.—The finished door: *a*, door showing outer face and cleats; *b*, section of side wall showing how door fits.

nailed to the other strips. After the doors are cut, bolt the silo to the eyebolts shown in figure 5.

A continuous door.—Sometimes a continuous door in the silo is desired. This door is a little more convenient than doors at intervals, but produces no better results and is decidedly more difficult to construct. In putting a continuous door in a stave silo, a door frame should be made of 4 by 6 inch timbers which are kept 20 inches apart by means of pieces of pipe and are fastened together by means

of bolts passing through the posts and pipes, as shown in figure 15. Iron washers should be placed between the ends of the pipe and the timbers to prevent the pipe from sinking into the timber. Washers should also be used under the boltheads and nuts.

When the door frame is complete it should be put in position, plumbed, and securely braced, after which the staves should be put up, as previously described. The doorposts should be flush with the

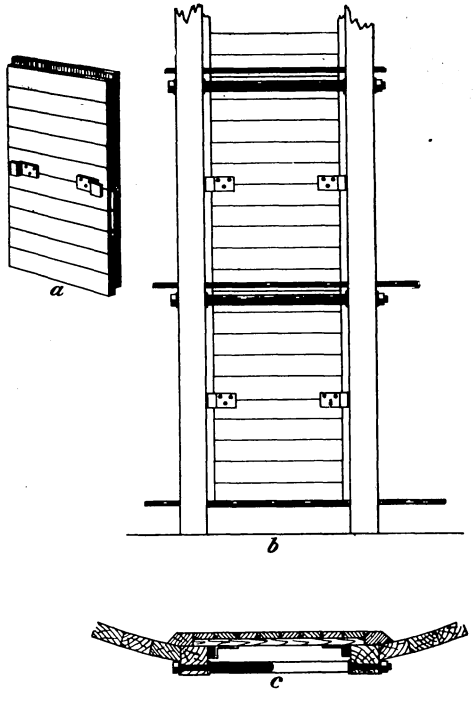

FIG. 15.—A continuous door: *a*, a section of the door; *b*, door frame with doors in position; *c*, cross section showing door and frame.

staves on the inside. On the outside they will project beyond the staves, and holes should be bored in these projections to permit the hoops to pass through.

Doors for this frame are made of two thicknesses of tongued and grooved flooring with tarred paper between, the inside flooring running vertically and the outside horizontally. The doors are held in position by means of iron straps, one on each side, which project over a slat nailed to the doorpost. When the silage is being used, instead of the doors being removed from the frames they are slid up out of the way and held by a pin in the doorpost. The topmost door will have to be taken out, and this will make room for the other doors to be raised one at a time enough to give an opening.

As shown in figure 15, the doors are so made as to overlap where they meet and thus make a tight joint. Patented doors with suitable frames can be purchased, but their advantage is not in proportion to their cost.

THE ROOF.

It is not necessary for the keeping of silage that the silo be roofed, but a roof adds to the appearance and life of the building and to the comfort of the men getting out feed on stormy days. Figure 16

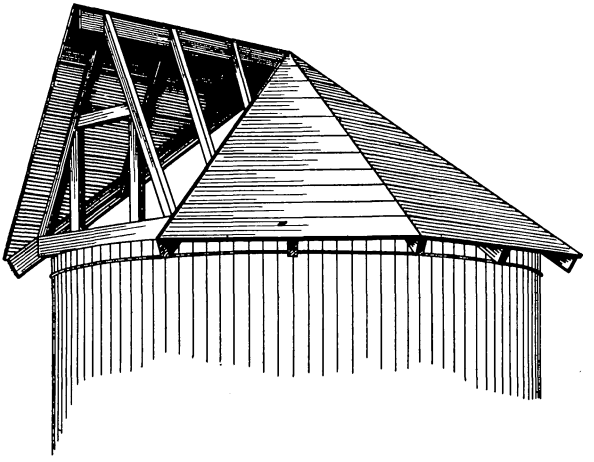

FIG. 16.—Roof with door in gable.

shows the framing and boarding for a good type of roof, with the door for filling the silo in a gable.

Figure 17 shows the same roof as figure 16, but with a trapdoor for filling, in place of the door in the gable.

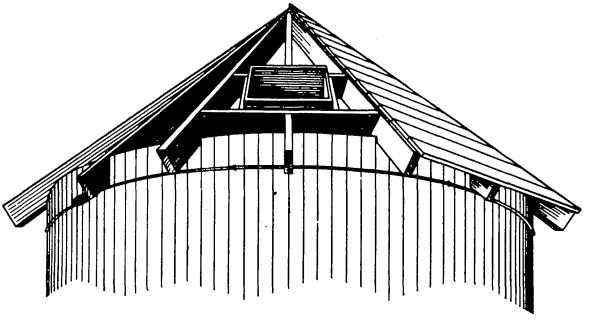

FIG. 17.—Roof with trapdoor for filling silo.

LADDER AND CHUTE.

A ladder should be attached to the silo at one side of the doors, and a chute, through which to remove the silage, should be built so as to inclose the ladder and the doors, as shown in figure 18. This

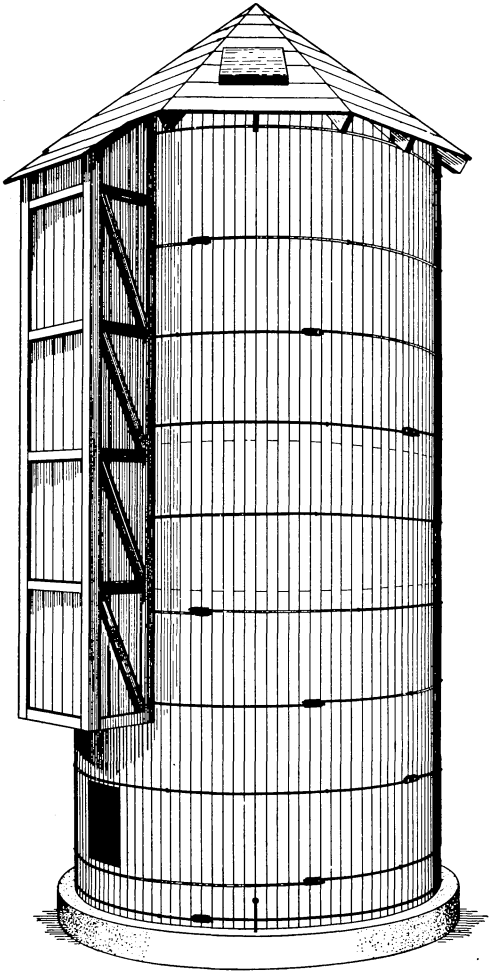

FIG. 18.—Complete silo with chute

should be large enough to permit a man to climb the ladder conveniently. In case the continuous door is adopted, the ladder may be dispensed with, as the hoops will serve for steps. (See fig. 15.)

PAINTING.

Before the silo is filled it should be painted on the inside with coal tar thinned with gasoline. Every two or three years a fresh coat of this paint should be put on. When the timber in the silo is thoroughly dry, the outside of it should be painted to conform with the surrounding buildings.

BILLS OF MATERIAL.

One of the main questions which will confront the farmer who undertakes to build his own silo is, "What materials will I need and how much of each kind?" Owing to the variation in size of silos, it is impracticable to give such information in detail here. If any farmer who desires such information will address a request to the Dairy Division, Bureau of Animal Industry, United States Department of Agriculture, stating the size of silo he proposes to build, a complete list of the materials needed will be forwarded to him free of cost.

Approved:

JAMES WILSON,
Secretary of Agriculture.

WASHINGTON, D. C., *September 23, 1908.*

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